REMARKS

Of originally filed Claims 1 - 29, Claims 6, 12 - 13, 15, 21, and 27 - 28 are withdrawn pending a determination that generic, linking, Claims 1 and 16 are allowable. Claims 1- 5, 7, 8, 10, 11, 16 - 20, 22, 23, 25, and 26 have been rejected as anticipated under 35 U.S. C. 102 by the disclosure of the Ono et al U.S. Patent No. 6,122,585. Claims 9, 11 and 24 have been rejected under 35 U.S.C. 112 as lacking antecedents for claim elements. The indication of allowability of the subject mater of Claims 9, 14, 24, and 29 is appreciated.

Claims 9 and 24 have been amended to expressly recite implied conditions or states in the preamble that are referenced in the body of the claims. Claim 11 is amended to properly introduce, rather than reference, the "off-command" and "on-command". In addition, an error in the second paragraph of Claims 11 and 26 is corrected ("falls below" changed to "exceeds"--compare to the first paragraph). These changes are supported in the specification (see paragraph 20) and do not introduce any new matter and are not intended to nor actually do further limit these claims or any other claims dependent upon these claims. Reconsideration of the pending claims in light of the amendments to Claims 9, 11, 24, and 26 and the following comments is requested.

The Examiner has pointed to many parts of the extensive Ono patent as anticipating various claimed elements and steps of the rejected claims. However, the Examiner has not pointed to any part of Ono that explicitly teaches:

> [means for] processing the measured wheel angular speed in a sliding mode observer to calculate an estimated differential wheel torque, wherein said differential wheel torque represents the difference between wheel drag torque, generated at the interface of the tire and the ground surface, and applied braking torque;

of the independent Claims 1 and 16. The Examiner simply cites the Ono Abstract, which reads as follows:

> An anti-lock braking system includes a friction torque gradient estimating unit for estimating, from a small number of parameters, the gradient of friction torque with respect to a slip speed, and controls a braking force acting on wheels on the basis of the friction torque gradient estimated by the friction torque gradient estimating unit. The

> friction torque gradient estimating unit may employ several types of estimating methods; e.g., a method of estimating the gradient of friction torque from only time-series data concerning a wheel speed; a method of estimating the friction torque gradient from time-series data concerning wheel deceleration as well as from braking torque or time-series data concerning physical quantities associated with the braking torque; or a method of estimating the friction torque gradient from micro-gains which are obtained when brake pressure is excited in a very small amount at the resonance frequency of a vibration system comprising a vehicle, wheels, and a road surface and which represent the characteristics of the vibration system. Further, there is also disclosed a method of determining, from the thus-estimated friction torque gradient, the limit of the characteristics of friction torque developed between the wheels and the road surface.

Apparently, the Examiner is equating the "gradient of friction torque" (also called "friction torque gradient" in the detailed description) with the "estimated differential wheel torque" derived by the SMO from wheel speed in accordance with the present invention. Therefore, it is assumed that the Examiner is relying upon the statement, "The friction torque gradient estimating unit may employ several types of estimating methods; e.g., a method of estimating the gradient of friction torque from only time-series data concerning a wheel speed . . ." (which apparently corresponds to the embodiment of FIG. 1 or 19) in finding the claims anticipated by Ono et al. The other Ono et al embodiments also estimate the friction torque gradient but appear to also rely upon sensors that can detect and measure "friction-torque", "wheel deceleration" and "braking-torque" (FIGs. 2 and 3 taken together) or "wheel speed" and sensors and processor 42 that develop a "brake pressure micro-amplitude" signal (FIG. 4).

The following response is based on these assumptions, and clarification is requested if these assumptions are incorrect. The Examiner is also requested to clarify the basis of his rejections if repeated. For example, the Examiner's reference to column 6, line 57, to column 7, line 15, as describing "generating a threshold wheel torque from measured wheel angular speed" of Claims 1 and 16 is not understandable. Similarly, the Examiner's reference to column 43, line 57 - 68 that describe filtering the wheel speed signal per FIG. 14 in reference to the cited language of Claims 3 and 18 relating to filtering to smooth on-command

and off-command signals is not understandable. Precisely what language in Ono et al is being relied upon?

The terms that are used in the Ono et al patent and the present Ribbens et al application are confusingly similar but do not necessarily mean the same thing. Certain of the terms are defined in Ono et al at col. 7, lines 27 - 60, at col. 11, lines 16 -20, col. 8, line 54 to col. 9, line 17, and perhaps elsewhere in the specification.

It is believed that the "friction torque" employed by Ono et al corresponds to the road/tire friction torque or "wheel drag torque" T_b employed by Ribbens et al. Ono et al also recite a "braking torque" designated T_b, but that corresponds to the brake torque applied to the wheel or "applied braking torque" designated T_a in the present Ribbens et al application. Ribbens et al and Ono et al employ similar terms for to wheel speed measurements (ω_i in Ono et al and ω_{meas} in Ribbens et al), wheel slip s, velocity V, and friction coefficient μ.

When Ono et al refer to "friction torque gradient" k_i (see col. 11, lines 16 - 20), they mean "friction torque gradient with respect to the slip speed" as set forth at col. 9, lines 13 - 15. "Slip speed" is defined at col. 8, line 62, to col. 9, line 4 as ω_s, where $\omega_s = \omega_v - \omega_i$, and ω_v is the vehicle speed expressed as an angular velocity and ω_i is the wheel speed of the *ith* wheel expressed as an angular velocity. "Slip speed" ω_s is therefore apparently a "wheel slip speed" and is alternatively designated x_i at col. 12, lines 18 - 19.

Ono et al are deriving an estimate of the change in friction torque (ΔT_b in the notation of Ribbens et al) from differences between successive wheel speed ω_i. measurements ω_i;[k], ω_i;[k-1], ω_i;[k-2], etc (or $\Delta\omega_i$). Ono et al also need to know the corresponding change in slip speed, $\Delta\omega_s$, which can be directly related to the change in wheel speed, $\Delta\omega_i$, for the *ith* wheel assuming the measurement time steps are small. Thus, the friction torque gradient that Ono et al estimate corresponds to $\Delta T_b/\Delta\omega_s$ Computing this gradient involves estimating changes in friction torque and wheel speed over two different, albeit closely spaced, points in time.

By contrast, the SMO estimate $\Delta\hat{T}$ of differential wheel torque ΔT employed by Ribbens et al and appearing in the independent claims is an estimate of the instantaneous difference at a single point in time between the wheel drag torque T_b, and the applied braking torque T_a applied (by hydraulic pressure or an electric motor) to the wheel(s). The SMO estimates the differential wheel torque $\Delta\hat{T} = (T_b - T_a)$ by closely tracking measured values of each discrete wheel speed (ω_{meas} in Ribbens et al) and uses this net torque estimate to control the pressure applied to the brakes. This is a far simpler approach that does not rely upon determining ω_i;[k], ω_i;[k-1], ω_i;[k-2], etc. or $\Delta\omega_i$), from successive wheel speed ω_i measurements. Moreover, the $\Delta T_b/\Delta\omega_s$ estimate that Ono et al seek is simply not needed by Ribbens et al when computing the estimate of the differential wheel torque $\Delta\hat{T} = (T_b - T_a)$.

Therefore, the goal of the Ono et al estimator is to obtain an estimate of the gradient of friction torque with respect to slip s. This is a different variable than that obtained in Ribbens et al via use of the SMO. In Ribbens et al, an estimate is obtained using the SMO of the difference between friction torque and applied torque. It cannot be emphasized too strongly that these are two different variables that are obtained using two different estimators. As explained further below, Ono et al use an on-line parameter estimator (i.e., a form of Kalman filter) estimator in contrast to the SMO used by Ribbens et al and claimed in all of the pending claims.

Ono et al need an accurate value for instantaneous angular acceleration, and his equations serve to obtain this from the noisy "variation in wheel speed" measurements, that is the mathematical difference $\Delta\omega_i$ between successive wheel speed ω_i measurements. However, the goal of Ono et al is not to estimate the angular acceleration accurately but to derive an estimate for the magnitude of the wheel drag torque T_b and how it changes (i.e. its gradient) with changes in wheel slip speed ω_s. The SMO approach of the present invention achieves the same degree of ABS control with only incomplete knowledge of the true state of the system model. In particular, the magnitude of the road/tire friction or wheel drag torque T_b is not explicitly estimated by Ribbens et al nor is it differentiated

with respect to time or to slip s in order to compute a gradient similar to the friction torque gradient estimated by Ono et al.

Referring to FIG. 2 of the Ribbens et al application, the SMO estimate $\Delta\hat{T}$, appearing at the output of the low pass filter 14, will closely track the instantaneous differential wheel torque ΔT, assuming the SMO gain K (item 24) is sufficiently large to guarantee stability. In the SMO based approach to anti-lock braking, the error between the measured wheel speed, ω_{meas}, and the SMO computed value for the wheel speed state is always driven to zero. The "sliding" action of the wheel speed measurement error to zero is due to the action of the sgn or signum function in the integration loop and a sufficiently high K to insure stability of the SMO. Note that the computed wheel speed appears at the output of the integrator 16 in the SMO loop of FIG. 2. Note also that operation near the peak of the µ-slip curve can be obtained by controlling the braking based on a suitable fixed or variable threshold for the SMO output signal ΔT^.

The mathematical formulae developed by Ono et al exhibit an attempt to closely estimate the gradient of the road friction torque, T_b, with respect to wheel slip. To obtain this desired estimate Ono et al first must estimate two other time varying wheel variables given the wheel inertia, J. Ono et al do this via a linear estimator following the equations appearing in columns 10 through 14, which are very similar to those of the well-known, discrete state and discrete observation, Kalman filter.

In Ono et al, the instantaneous angular acceleration is one of the two elements in his Kalman filter state vector, $\theta_i[k]$, estimated at time step k. By definition the angular acceleration is the first time derivative of the angular wheel speed ω, i.e., $d\omega/dt$. The second element in Ono's state vector is the rate of change of the angular acceleration, i.e., the angular "jerk". Mathematically, this is the second time derivative of the wheel speed, $d^2\omega /dt^2$. However, as noted above, this is just one step in the Ono et al estimation process, with the ultimate quantity estimated being the gradient of the road friction torque (T_b in Ribbens) with respect to wheel slip. It is extremely important to note that T_b is not the same as the ΔT estimated by Ribbens et al with the sliding mode observer.

By contrast, the single state variable in the SMO of Ribbens et al is the angular velocity, ω, not the angular acceleration or the angular jerk. This SMO state variable closely tracks the real wheel speed and appears at the output of the integrator block 16 (1/s block, where s is the Laplace operator) in FIG. 2 of Ribbens et al. Now, from basic mechanics, the net differential wheel torque, ΔT, is directly proportional to the instantaneous wheel angular acceleration, with the ratio of differential torque to angular acceleration being the wheel inertia J in FIG. 2 of Ribbens. Thus, the input to the integrator in the SMO of Ribbens et al must represent a signal proportional to the angular acceleration or ΔT.

Ribbens et al realized this last point but first applies a low pass filter 14 to the signal tapped from the SMO's integrator input in order to obtain a smoothed estimate for the instantaneous ΔT, the SMO output signal ΔT^ as shown in Figure 2. The low pass filter (or other equivalent filtering scheme) removes any large amplitude swings due to the sgn and gain blocks, 22 and 24 respectively in Figure 2, from the SMO estimate $\Delta\hat{T}$. The value of $\Delta\hat{T}$ then accurately tracks the instantaneous angular acceleration and hence instantaneous ΔT of the vehicle. There is simply no mathematical similarity between the Kalman filter based linear estimator of Ono and the SMO based linear estimator of Ribbens.

In addition, and perhaps even more importantly, the control strategies set forth by Ono et al and Ribbens et al for applying the wheel brakes are vastly different. The Ono et al strategy is to limit the magnitude of the rate of change of friction torque with respect to slip so as to remain at the peak of the μ-slip curve. This requires considerable more computation beyond estimating the angular acceleration. The Ribbens et al strategy is simply to limit the negative swings of the smoothed differential wheel torque estimate $\Delta\hat{T}$ obtained from the SMO. This is because $\Delta\hat{T} = (T_b - T_a)$, and a large negative value for $\Delta\hat{T}$ would indicate excessive braking and/or a reduction in the road/tire friction or wheel drag torque T_b due to a high wheel slip condition.

In conclusion, an SMO based estimate of differential wheel torque, $\Delta\hat{T}$, will have the property that it can be used to control the brake on/off application in a very efficient manner given a properly chosen threshold which can be fixed or

dynamically varied. There is no need to estimate the gradient of the friction, or drag, torque with respect to slip, time or any other variable to achieve near-optimal braking. Furthermore, Ono et al and Ribbens et al employ totally different linear estimators and braking control strategies based on their respective estimates.

It is respectfully requested that the claims are therefore allowable and that the restriction requirement be withdrawn and all pending claims be examined simultaneously and allowed. The Examiner is respectfully invited to telephone the undersigned to discuss the claims and the reasons that he may have for maintaining the rejections.

Dated: December 3, 2003

Respectfully Submitted,

By: Joseph F. Breimayer

Joseph F. Breimayer
Registration No. 25,551

BREIMAYER LAW OFFICE
1221 Nicollet Mall, Suite 206
Minneapolis, MN 55403
Telephone: (612) 338-1279
Fax: (612) 338-0910

MARKED-UP CLAIMS

9(Amended). The method of Claim 8, wherein the measured wheel angular speed varies between maximum and minimum wheel angular speeds exhibiting ~~exhibits~~ speed amplitude peaks and valleys with intermittent changes in wheel slip, and the step of generating a skid signal comprises:

defining a moving time window;

detecting a plurality of the peaks and/or the valleys of the wheel angular speed over the moving time window;

determining a smoothed version of the maximum wheel angular speed from the plurality of peaks via averaging or filtering and/or determining a smoothed version of the minimum wheel angular speed from the plurality of valleys via averaging or filtering;

deriving a reference vehicle velocity from knowing that the smoothed maximum wheel angular speed must be associated with a minimal value of instantaneous slip and/or the smoothed minimum wheel angular speed must be associated with a maximal value of instantaneous wheel slip; and

deriving the skid signal from the derived reference vehicle velocity and the measured wheel angular speed proportional to the instantaneous wheel slip.

11(Amended). The method of Claim 1, wherein the step of generating a braking control signal comprises:

generating ~~the~~ an off-command braking control signal that commands the brake actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque falls below the threshold differential wheel torque; and

generating ~~the~~ an on-command braking control signal that does not command the actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque ~~falls below~~ exceeds the threshold differential wheel torque.

24(Amended). The system of Claim 23, wherein the measured wheel angular speed varies between maximum and minimum wheel angular speeds exhibiting ~~exhibits~~ speed amplitude peaks and valleys with intermittent changes in wheel slip, and the means for generating a skid signal comprises:

means for detecting a plurality of the peaks and/or the valleys of the wheel angular speed over a moving time window;

means for determining a smoothed version of the maximum wheel angular speed from the plurality of peaks via averaging or filtering and/or determining a smoothed version of the minimum wheel angular speed from the plurality of valleys via averaging or filtering;

means for deriving a reference vehicle velocity from knowing that the smoothed maximum wheel angular speed must be associated with a minimal value of instantaneous slip and/or the smoothed minimum wheel angular speed must be associated with a maximal value of instantaneous wheel slip; and means for deriving the skid signal from the derived reference vehicle velocity and the measured wheel angular speed proportional to the instantaneous wheel slip.-

26(Amended). The system of Claim 16, wherein the means for generating a braking control signal comprises:

means for generating a braking control signal off-command that commands the brake actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque falls below the threshold differential wheel torque; and

means for generating a braking control signal on-command that does not command the actuator to interrupt application of the brake to the wheel when the estimated differential wheel torque exceeds ~~falls below~~ the threshold differential wheel torque. --

-